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GPU-accelerated collaborative task scheduling algorithm optimization Adobe After Effects movie special effects rendering optimization research

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Abstract Movie special effects technology is mainly composed of three categories: live action special effects, computer-generated special effects and hybrid special effects. This paper mainly analyzes the development of movie special effects technology from the aspect of computer-generated special effects, combined with Adobe After Effects video editing software. Combined with the common visual special effects technology in modern movies, and the changes in the production method of modern movie special effects, this paper proposes the use of virtual simulation technology, including texture mapping technology, virtual reality technology, etc. to design a movie animation special effects system based on three-dimensional virtual technology. The wavelet decomposition is used to process the three-dimensional image, extract the image edge information, use virtual reality technology to obtain the a priori knowledge points of the image, obtain the minimum recognition distance of the scene picture, improve the overall signal-to-noise ratio of the image, and realize the surface reconstruction of the three-dimensional scene image. The virtual scene generated by the movie animation special effects system is compared with the real phenomenon, demonstrating that the virtual generation effect of the multi-factor scene is closer to the real effect. Among them, 34 volunteers think that the movie animation special effects system in this paper has more excellent stability, which indicates that the movie animation special effects system based on 3D virtual technology can be practically applied.

Index Terms virtual simulation technology, texture mapping technology, three-dimensional images, virtual scenes, movie special effects technology

I. Introduction

The era of special effects in cinema began with the Méliès era to the Lucas era, and was then interpreted by directors Spielberg and Cameron in a new era of special effects in cinema [1], [2]. Special effects technology has become not only an art form for film creators and directors, but also an important tool for storytelling. At the same time, special effects technology has attracted many moviegoers' demand for visual enjoyment of movies, and has also vigorously promoted the vigorous development of the movie market [3]-[7]. In the Hollywood movie production industry, movie special effects technology has become an indispensable part of the current Hollywood movie industry as well as movie production content [8]. Today's movie special effects production industry has become an important division of labor in the filming and creation process.

In the introduction of literature [9], visual special effects technology improves the help for post-editing and special effects creation of film and television works, which mainly creates and optimizes the picture and sound effects in the works to obtain higher artistic value. Literature [10] analyzed that the special effects synthesis technology and film digital technology in the movie “Wandering Earth” accounted for 70% and 55% in the early and post-production of the movie, respectively. And with the continuous development of technology, special effects technology ushers in new opportunities. Literature [11] mentions that multimedia information technology has innovated editing methods and concepts in the post-production of special effects in film and television, which promotes the enhancement of the expressiveness and influence of special effects designers. Literature [12] introduces that 3D technology supports animation special effects combining display and virtualization, which can make film and television works obtain excellent visual impact and artistic expression. Literature [13] with visual communication design-led animated film special effects production optimizes the visibility and information transfer effect of film works, reduces the production cost, and improves the attention of young groups. It can be seen that the movie special effects technology to perfect the picture and has realized the reality of the shooting process irreplaceable lens, and the film content is a blend of one, inseparable, in order to achieve the common composition and realization of the movie to be expressed to the audience's visual enjoyment. The technical nature is often reflected in the whole process of realizing various visual effects from the conception to the completion of the final picture [14]. The practical function of movie special effects is reflected in the creation of complex visual effects that are difficult to film, and the realization of this function depends on the use of technical means [15], [16]. On the artistic level, due to the superb image realization ability of film special effects, the use of this means is usually easier to induce or reflect the creator's artistic intention, and its development shows the subjective path of the creator's pursuit of film art from a certain perspective [17]-[20]. Therefore, technicality is one of the most important factors reflecting the development of film special effects.

In the creation of the movie, the post-production of the adjustment of the production of the tools also with the development of information technology, such as the most commonly used post-production of the software Adobe After Effects (AE) of the update is very rapid [21]. Reviewing the release time and version upgrade of AE software, it can be found that basically from the release of AE1.0 in January 1993, every year in the upgrading of hundreds of preset effects and animation can be realized, with powerful stunt control, multi-layer editing, efficient keyframe editing, simultaneous rendering of multiple frames multiprocessing and other functions to achieve better visual effects [22]-[24]. Literature [25] points out that AE software and its plug-ins will display the images and scenes that cannot be realized in the shooting, and key elements are constructed in the software and plug-ins in order to realize the production of special effects and complete the special scenes. Based on this, the development of movie special effects technology supported by AE software is explored to provide reference for movie special effects production.

This paper analyzes the technical components of film special effects, Adobe After Effects video editing software, and its common concepts. Outline the historical development of visual effects technology, analyze the common visual effects technology in modern movies, and propose the differences between modern movies and traditional movies in terms of special effects production methods. Understand the main production steps of special effects in movies in three stages: pre-production, mid-production and post-production. Combine the key technologies of virtual simulation (texture mapping technology, etc.) to design a movie animation special effects system based on 3D virtual technology. Use wavelet decomposition to process the image texture information, realize the image preprocessing goal, then extract the image edge information, correct the image edges, and reconstruct the three-dimensional scene image using virtual reality technology. Analyze the real-time, scene automatic construction effect and animation effect of the movie animation special effects system.

II. Analysis of the technical development of film special effects

II. A.Movie special effects technology

Film special effects technology refers to the use of a variety of technical means in the film production process, through post-processing and synthesis to create an image effect that can not be realized through conventional means of shooting, including special effects, computer-generated special effects and mixed special effects of three categories.

Live-action special effects refers to the physical actual scene construction, modeling and special equipment used to achieve special effects. Computer generated special effects refers to the use of computer technology to generate virtual image effects. This special effects technology can create a variety of fantasy scenes, creatures and objects, such as the planet Pandora and the blue people in Avatar. Hybrid effects are a combination of live-action and computer-generated effects to create more realistic image effects. By combining live action and computer synthesis techniques, more complex and larger special effects scenes can be created.

II. B.Adobe After Effects video editing software

Adobe's BCC Motion Key Filter can be added as a functional plug-in to the company's video editing software, Adobe After Effects. For the input video material, it first needs to manually select the starting and ending positions of the image sequence to be edited, and mark the object area to be erased in the video scene in the starting and ending frame images. Then the software will utilize the time domain correlation characteristics, using optical flow field technology to estimate the motion of the prefabricated area, and select the appropriate pixel area from the adjacent frames before and after the current area to fill in the current area to repair, thus deleting the target object in the corresponding area.

Steps to tamper with a video:

STEP1: Import the video to be edited.

STEP2: Delimit the area and motion range of the objects to be erased.

STEP3: Click the “show mask” button, you can see that the objects in the demarcated area are divided into two parts.

STEP4: The final result is a comparison of the original video on the left and the tampered video on the right.

Some common concepts in Adobe After Effects:

(1) Project

A project is a file that stores the synthesis and references to all the source files used by the material in that project. Project files use the file extension .aep or .aepx. Project files with the .aep file extension are binary project files, and project files with the .aepx file extension are text-based XML project files. By default, .aep is used as the file name extension.

(2) Composites

Composites are collections of layers, each with its own timeline. You can import material into a composite, then arrange the layers at the spatial and temporal levels, and composite using the transparency function to determine which parts of the bottom layer need to be shown through the layers stacked on top of it.

(3) Layers

Layers are the elements that make up a composite. Without layers, a composite is just an empty frame. Composites can be created using one or more layers as needed, with some composites containing thousands of layers and some containing only one. You can create multiple layers, for example:

a.Make video or audio layers based on imported material items, such as still images, movies, and audio tracks.

b. Create layers that are used to perform special functions in Adobe After Effects, such as: cameras, lighting, adjustment layers, and empty objects.

c. Create solid color layers based on solid color footage in Adobe After Effects.

d. Create compositing layers of visual elements in Adobe After Effects, such as: shape layers and text layers.

e. Pre-composite layers, which use existing composites as their source material.

Note that when modifying a layer, the source material is not affected, and you can use the same material as the source for multiple layers and use the material in different ways in each instance.

(4) Keyframes

Keyframes are used to set parameters for actions, effects, audio, and many other properties that often need to change over time. Keyframes mark a start time point and an end time point, between these two time points, you can set the many attributes of the layer (such as spatial position, opacity, volume, rotation angle, stereoscopic 3D effects, etc.), then between the start time point and the end time point will produce the effect of attribute values over time, thus forming an animation.

(5) Expressions

Expressions have a syntax similar to that of the JavaScript scripting language, and are used to specify the values of attributes as well as to relate attributes to each other. Simple expressions can be created by connecting attributes to associators.

(6) Rendering

Rendering is the process of creating successive frames from a composite. Rendering of frames is the process of creating a composite two-dimensional image based on all the layers, settings, and other information in the composite that makes up the image. Rendering of an animation is the frame-by-frame rendering of the frames that make up the animation. The primary way to render and export animation in Adobe After Effects is to use a render queue; after placing a composite in the render queue, the composite becomes a render item; multiple render items can be added to the render queue, and Adobe After Effects can batch-render multiple items with no one involved.

In addition to manipulating panels and buttons in the Adobe After Effects software interface to set up animations, you can write program code to generate animations through the ExtendScript API provided by Adobe After Effects.Ex-tendScript is based on the JavaScript syntax used in creating projects, compositing and rendering queues, they contain the following elements: movies, images, solid colors, layers, masks, effects, and attributes, and all of these elements are treated as objects in ExtendScript, so it is possible to write ExtendScript scripts to manipulate these objects, set attribute actions and trigger times for the specified composite objects to form a visually stimulating randomly moving signal animation, and finally rendering and exporting the animation.

II. C.Development of visual effects technology

II. C. 1) Historical development of visual effects technology

The application of visual effects technology can be traced back to the beginning of the 20th century. With the development of the film industry, people began to try to use various technical means to enhance the visual effects of films. The earliest visual effects used hand-drawn methods, such as painting and coloring techniques, which were mainly used to add color to the film or create special effects. As technology continued to advance, filmmakers began to use optical effects techniques such as layered photography, front and rear projection and slide compositing.

In the 1960s and 1970s, the advent of computer graphics led to a revolution in visual effects technology. Digital image processing and computer-generated imagery techniques provided more possibilities for movie production, such as adding special effects and creating fictional scenes and characters. Since then, computer-generated image technology has been widely used in movie special effects and has become an integral part of modern movie production.

II. C. 2) Common visual effects techniques in modern movies

There are a variety of visual effects techniques used in modern movies, the most common of which include the following.

3D modeling and animation: with the help of computer-generated imagery technology, filmmakers can create realistic three-dimensional models and animations of animals, monsters, and spaceships, as well as simulate natural phenomena and special effects.

Green and Blue Screen Technology: This technology allows filmmakers to composite actors and physical objects with fictional backgrounds during filming. Actors perform in front of a green or blue background, which is then synthesized with the virtual environment through post-production.

Digital Makeup: Digital makeup technology not only modifies an actor's appearance, such as changing skin color and adding special features, but also creates fictional characters. Digital makeup uses computer image processing to make the actor's makeup more realistic and enhance the character's expressiveness.

Simulated Particle Effects: With the help of computer simulation and analog technology, filmmakers can create realistic natural phenomena such as volcanic eruptions, storms, and smoke. Particle effects technology can simulate and control a large number of tiny particles to create realistic object movement and special effects.

II. C. 3) Differences and connections between traditional and modern approaches to movie special effects production

Traditional movie special effects production relies on physical effects and mechanical equipment, such as models, special props, flames and explosions. This kind of production requires a lot of on-site shooting and post-production work, and the process of creating special effects is more cumbersome. The production of modern movie special effects mainly relies on computer and digital image processing technology, which is more convenient and flexible, and can realize various special effects and virtual scenes through software and algorithms.

Nevertheless, there is still a connection between traditional and modern movie special effects production methods. Many modern filmmakers draw on the experience and techniques of traditional special effects production, such as the use of location filming and physical props to enhance the realism of special effects. The development of modern special effects technology offers new possibilities for traditional special effects production, such as the use of computer technology to improve the performance of special props, or the restoration of special effects in old films through digital technology.

II. D.Steps in the production of movie special effects

In the process of movie making, the visual illusions as well as hallucinations created by the movie screen either by human beings or by computers. In the process of movie production, they are called movie special effects also known as stunt effects. In order to avoid the actors in the shooting process in a dangerous performance situation and state, but also in order to reduce the production cost of the film during the shooting process, more is the use of film special effects to realize the reality of the shooting process is impossible to achieve the shooting scenes and the plot of the film as well as the audio-visual effects, the film will be used in the shooting of the film special effects technology to complete the film picture, so that the film's audio-visual effect is more heartwarming.

II. D. 1) Pre-preparation phase

The movie picture plays a leading role in the success of the movie work, the two key elements of the success of the movie special effects production are planning and technology, which is the root of the movie special effects.

Planning stage: the main purpose is to purposefully decide the idea of the movie special effects shot script.

Scripting stage: the main purpose is to design the script of the movie special effects shots before shooting the movie. The filming process of movie special effects shots is quite arduous and intolerable, because the cost of filming is quite high, so it is not allowed to have a high ratio of film consumption and time investment. Therefore, during the pre-production of the movie, the director and the special effects director, the director of photography and the art director must do a good job of communicating with each other and setting up a plan for implementation. Before the movie starts shooting, through the director and the director of photography designed by the scene scheduling, camera movement and actor positioning and CG screen processing content, to make the corresponding pre-written scripts and screen shots tableau and camera position diagram. And through a three-dimensional pre-shot software for dynamic demonstration, dynamic simulation of actors and camera scheduling.

Equipment technology stage: the main purpose is to prepare for the realization of film special effects production equipment and technical support.

After technical analysis, the movie special effects lens layering process, in order to make the background layer, character layer, foreground layer and special effects layer. For example: blast, fluid, particles, flame, cg character and so on, and then through the three-dimensional virtual camera to simulate the movement of the camera track. Prepare a list of hardware and equipment according to the needs of the director, director of photography and special effects director.

The art team will prepare the scene rendering according to the requirements, and the setup will prepare the setup and keying of the green or blue screen as well as posting the tracking points. The lighting crew will set up the lighting according to the camera movements and the actors' schedules. Finalize the shooting schedule and plan.

II. D. 2) Intermediate stage

With the pre-production of the movie quite well prepared, the production of the movie is also in the shooting process. In the shooting scene, the movie special effects are also in the middle stage. That is to say, after the director, special effects team and camera team have negotiated the shooting program and shooting plan, the movie on the shooting site is encountered in the need for special effects compositing or processing stage.

On-set Shooting Stage: The main purpose is to capture the character and background material shot on-set.

The special effects director, the art director, and the set designer will set up the scene according to the director's requirements. Background if there is a need to key and replace the scene, the cameraman and special effects and field recorders in the camera to maintain a fixed camera position at the same time, record the camera lens parameters, height and angle, will be with a blue screen or green screen role and not with the role of the empty scene shot twice. Then will use post-synthesis software nuke or ae and other software, the use of color keying will be blue or green screen keying, retaining the channel, the foreground character and empty scene or CG background synthesis in a picture.

II. D. 3) Later stages

After going through the pre-stage and intermediate stages, the live shot footage is obtained. Traditional cinematography utilizes film, so when creating in the post stage, first, the film is developed, and then it is transferred to obtain a digital intermediate. After going through the post-production process of editing and special effects and color grading.

Most of today's cinematography is shot by digital video cameras, and the mainstream ones on the market include machines such as the RED epic and Ale's Alisa. The imaging of digital cameras is RAW data. Therefore, the footage is stored in the camera's memory card as well as on the hard disk.

The production process of the digital video camera is to use REDCINE or DAVINCI for digital transcoding of raw data. The post-production software used in the movie mainly includes graphic image graphic design software, post-production special effects synthesis software, non-linear editing software, three-dimensional production software, and so on.

III. Design of movie animation special effects system based on 3D virtual technology

III. A. Virtual Simulation Key Technology

Texture mapping is a technique for drawing (mapping) graphics onto a surface, which can significantly increase the detail and realism of the scene being drawn. The principle of texture mapping has two main steps. The first step is to map the texture coordinate system to the object coordinate system. The second step is the mapping of the object coordinate system to the window coordinate system. The principle of texture mapping is to assign color values to the vertices on the surface of the model through an algorithm. To accomplish texture mapping first get the texture image. Then a mapping function is established, which can reflect the process of mapping a 2D texture image to a 3D object surface, and a reasonable choice of the mapping function can directly affect the effect of the 3D object surface after it is endowed with a texture image [26].

For a simple illumination model, the texture is obtained by changing the properties of the model surface. The ordinary illumination model has the following expression:

$$I = I_a K_a + I_p + K_d (N \cdot L) + I_p K_s \cdot (N \cdot S)^n \tag{1}$$

In the above equation, I_a represents the light intensity, K_a represents the reflection coefficient. I_p is the incident light intensity, K_d is the diffuse reflection coefficient, and K_s is the specular reflection coefficient. As can be seen from the calculation formula of the ordinary light model, by changing the normal vector of a certain surface of the model or changing the size of the value of the diffuse reflection coefficient, the color attributes of the model itself can be set, and the texture effect that meets the requirements can be obtained through the above process.

Spherical texture mapping is actually the determination of a functional relationship between the texture coordinates (u,v) mapped to the spherical coordinate system, and the expression of this functional relationship is as follows:

$$(u,v)=(\theta,\varphi),(0\le\theta\le\pi/2,\pi/4\le\varphi\le\pi/2) \tag{2}$$

The parameters of the sphere surface can be represented by the following equations:

$$\begin{cases} x=r\cos\varphi\sin\theta \\ y=r\cos\varphi\sin\theta \\ z=r\cos\varphi \end{cases} \tag{3}$$

The rectangular coordinate system is mapped to the sphere coordinate system by a linear transformation:

$$\begin{cases} u=\dfrac{\theta}{2\pi} \\ v=\dfrac{\varphi}{\pi} \end{cases} \tag{4}$$

The final mapping relation is found:

$$\begin{cases} u=\dfrac{\arctan(y/x)}{2\pi} \\ v=\dfrac{\arccos z}{\pi} \end{cases} \tag{5}$$

Cylinder surface texture mapping maps points in a rectangular coordinate system to the surface of a cylinder, which is similar to spherical texture mapping. Assuming that the height of a cylindrical surface is h and the radius is r, the functional relationship of the transformation has the following expression:

$$(u,v)=(\theta,\varphi),(0\le\theta\le\pi/2,\pi/4\le\varphi\le\pi/2) \tag{6}$$

The surface of the cylinder can be represented by the following parametric equations:

$$\begin{cases} x=r\cos u\sin v \\ y=r\sin u\sin v \\ z=r\cos v \end{cases} \tag{7}$$

mapped to the surface of the cylinder after a linear transformation:

$$\begin{cases} u=2\pi s/3 \\ v=\dfrac{\varphi}{\pi} \end{cases},0\le s,t\le 1 \tag{8}$$

Mapping relations from rectangular coordinate system transformations to cylindrical surfaces:

$$\begin{cases} u=\tan^{-1}(y/x) \\ v=z \end{cases} \tag{9}$$

Inverse conversion after linear transformation:

$$\begin{cases} u=\dfrac{3u}{2\pi}=\dfrac{3}{2\pi}\tan^{-1}(y/x) \\ t=v=z \end{cases} \tag{10}$$

Planar texture mapping is the mapping of points on a plane to a texture coordinate system. The mapping process of planar texture mapping: there is a plane ABCD, which is mapped to the texture coordinate system when $|AB|=|CD|=|X|$, $|BC|=|AD|=|Y|$. The mapping function of planar texture mapping has the following expression:

$$\begin{cases} u=\dfrac{1}{X}x+\dfrac{1}{2},-\dfrac{X}{2}\le x\le\dfrac{X}{2} \\ v=\dfrac{1}{Y}y+\dfrac{1}{2},-\dfrac{Y}{2}\le y\le\dfrac{Y}{2} \end{cases} \tag{11}$$

According to the design requirements of system development, this paper selects Unity 3D to carry out virtual simulation. In the Unity 3D engine, three main interaction methods are used: ray detection technology, collision detection technology and particle effects technology.

(1) Ray detection technology

(2) Collision detection technology

In the 3D interaction of virtual reality engine, collision detection technology is the most common interaction method.

Each object in the 3D model can be wrapped with a minimal ball, and such a wrapped ball is called collider in 3D interaction engine. Determining the radius and center of the enclosing ball is the most important step in the enclosing ball algorithm. Assuming that the projection intervals of the points in the 3D model on the 3D coordinate axes are: $[x_{\min}, x_{\max}], [y_{\min}, y_{\max}]$, $[z_{\min}, z_{\max}]$, the center of the enclosing ball has the coordinates (cx, cy, cz), and the radius of the enclosing ball is r, then the following relational expression is given:

Coordinates of the center of the enclosing sphere (cx, cy, cz):

$$cx = 1/2(x_{\min} + x_{\max}), cy = 1/2(y_{\min} + y_{\max}), cz = 1/2(z_{\min} + z_{\max}) \tag{12}$$

The radius of the encircling ball:

$$r = 1/2\sqrt{(x_{\max} - x_{\min})^2 + (y_{\max} - y_{\min})^2 + (z_{\max} - z_{\min})^2} \tag{13}$$

The enclosing sphere is represented by the following function:

$$R = \{(x, y, z)^T \mid (x - cx)^2 + (y - cy)^2 + (z - cz)^2 < r^2\} \tag{14}$$

The OBB Wraparound Box is an algorithm evolved from the Wraparound Sphere, where the model is wrapped by the smallest rectangle with respect to the axis direction, which serves as the collider of the OBB Wraparound Box. Assuming that the 3D model is composed of countless triangles, the size of the OBB wrapper is obtained by calculating the minimum and maximum values of the triangular elements of the model on the axis of the local region of the OBB wrapper.

The three directions of the three-dimensional space in the OBB enclosing box are represented by the covariance matrix eigenvectors calculated in the above equation, and x, y, z is used as the direction vector of the three axes of the three-dimensional space coordinate system, so that the projection range of the triangular elements on the three-dimensional space coordinate axes is: $[x_{\min}, x_{\max}], [y_{\min}, y_{\max}], [z_{\min}, z_{\max}]$, and the center of the final resulting enclosing box is: $center = 1/2(x_{\max} + x_{\min})x + 1/2(y_{\max} + y_{\min})y + 1/2(z_{\max} + z_{\min})z$.

(3) Particle Effects Technology

Particle system is a method of creating dynamic special effects for scenarios that require a large number of particles to be represented, such as rain, snowstorms, smoke, etc. Particle system has three main components, namely particle emitter, particle animator and particle renderer.

III. B. 3D Scene Image Preprocessing

In a real reconstruction environment, the edges of the 3D scene are blurred, and a variable amount of noise signals will exist within the collected image signals. In order to remove redundant data within the 3D scene image and ensure the image surface reconstruction rate, the 3D image is preprocessed [27]. The first step is wavelet decomposition to process the image texture information. Assuming that the relative filter index matrices of scale function $\gamma(x)$ and wavelet function $\omega(x)$ are Z, C respectively, and describing the 3D scene image $f(x, y)$ as C_0, the wavelet decomposition processing process is:

$$\begin{cases} C_{i+1} = ZC_iZ'; E_{i+1}^h = CC_iZ' \\ E_{i+1}^v = ZC_iC'; E_{i+1}^d = CC_iC' \end{cases} \tag{15}$$

where $E_i + 1^h, E_{i+1}^v, E_i + 1^d$ is the horizontal, vertical and diagonal constants of the 3D scene image in turn.

Wavelet decomposition has no compression function, and the wavelet processed image and the initial image features together form the image compression phenomenon, which is mainly presented in the low-frequency, horizontal, vertical and diagonal parts of the image with very low energy. When quantizing the compressed image, because the three-dimensional scene image display does not need to specify the region of interest, the size of the critical value can be disregarded when realizing the image surface reconstruction, and it is sufficient to set a critical value that can represent the global image. During image preprocessing, the result of the image presentation can be changed along with the change of the distance between the visual point and the image, and within the image where the visual point is farther away, a critical value $\varepsilon(d_i)$ with a larger value is picked so as to have a larger index. If the distance between the visual point and the image is close, the distance is d_i. The corresponding critical value $\varepsilon(d)$ can be used to perform the difference operation between the two distances, and the operation process is:

$$\log(\varepsilon(d)) = \frac{d - d_j}{d_i - d_j}\log(\varepsilon(d_j)) + (1 - \frac{d - d_j}{d_i - d_j})\log(\varepsilon(d_i)) \tag{16}$$

After obtaining the $m+1$th critical value, $m+1$ compressed files can be obtained, mobilizing different image files at different spacing, completing the image quantization coding and selecting the best critical value to achieve the goal of image preprocessing. After the image preprocessing, the next step is to extract the image edge information, correct the image edges and improve the quality of the reconstructed image.

III. C. Animated special effects system structure

The development platform adopts Window10 system and Framework, based on particle theory, using MAXScript scripting language development, mainly realizes the rain, snow, fountain and other realistic animation effects.

Three-dimensional virtual technology based on the movie animation effects system structure using B / S model, mainly by the system representation layer, animation effects logic layer, data access layer. Based on three-dimensional virtual technology animation effects system structure shown in Figure 1. In the figure, the data access layer stores user animation special effects data. Animation effects logic layer provides users with special effects tools to realize animation effects production, the layer can play a role in the overall structure of the system. The system representation layer, i.e. the client application, provides the user interface, which is responsible for the dialog function between the user and the application. The user interface mainly includes login and application functions, i.e. in the login interface, the user enters the account password. If the password is incorrect, the user will continue to enter the password and will not be able to enter the interface. If the account and password are correct, the user enters the layer. At this time, the user can use this layer to mobilize the animation effects logic layer and data access layer related functions, animation effects production and animation effects to view.

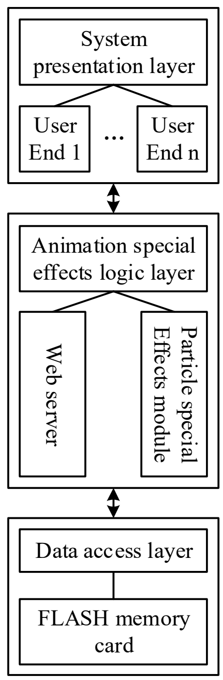

Figure 1: Animation effect system structure based on 3d virtual technology

III. D. Surface Reconstruction Algorithm for 3D Scene Images

The virtual reality technology is used to calculate the minimum recognition distance of the three-dimensional scene screen, complete the accurate matching of different three-dimensional point clouds, and realize the reconstruction of the target on the surface of the image. If the three-dimensional virtual targets measured by the virtual reality equipment are point light sources, two point light sources into the optical part of the virtual reality equipment will constitute the Airy spot, if the zero point of the edge of a certain Airy spot and the center of another Airy spot overlap, the spacing between the two Airy spots is the furthest distance that can be discriminated by the virtual reality equipment, which is recorded as:

$$\delta = l\frac{1.22e}{D} \tag{17}$$

where l is the spacing between the 3D virtual target and the virtual reality device. e is the wavelength of light into the virtual reality device. D represents the diameter of the optical flux.

From the above equation, it can be seen that the shorter the light wave is, the smaller the maximum distance that can be recognized by the optical part in the device. Three-dimensional scene graphic information utilizing the optical part in the device is received by the image detector and converted into an electrical signal. If the two three-dimensional virtual targets obtained by the image detector remain point light sources, the image detector image element is g , and only if the distance between the two point light source targets is large, they will be received by the image detector and will be recognized within the output image.

As seen above, the image detector resolution is higher than the scene picture optical diffraction resolution, and using virtual reality technology can obtain a priori knowledge points from within the image and obtain the minimum recognition distance of the scene picture to improve the overall signal-to-noise ratio of the image.

Compared with the traditional image surface reconstruction method, the image reconstruction method using virtual reality technology has more excellent noise suppression function and truncated projection information function, which is a composite iterative method. This method not only preserves the convergence rate of traditional image reconstruction methods, but also has the absolute advantage of low noise, which is highly practical.

The computational process of 3D scene image surface reconstruction under virtual reality technology is described as:

$$f^{(o+1)} = f^{(o)} + \lambda_o V^{-1} A^* W(p - Af^{(o)}) \tag{18}$$

where λ_o denotes the relaxation factor for image reconstruction. v and w represent the positive definite matrices of the N-order image and M-order image, respectively.

(1) Specify the projection ray i at a certain projection angle, and obtain the projection value $\sum_{n=1}^{N} a_{in} f_n^{(o)}$ of the i rd projection ray from the original value of the image to be reconstructed.

(2) Subtract the projection values obtained using the 3D scene image projection values and the projection values obtained from the real measurements to grasp the deviation between the theoretical image projection values and the real projection values, i.e.:

$$\Delta i = p_i - \sum_{n=1}^{N} a_{in} f_n^{(o)} \tag{19}$$

(3) Save the deviation value Δi in step (2).

(4) Extrapolate the $i+1$ nd ray projection value at a certain projection angle, and repeat the above three steps until all ray deviations are corrected.

(5) Modify the pixel values of the surface reconstruction image using the deviation values obtained in step (4).

For the remaining projection angles, the above steps are repeated until the reconstructed images are calibrated at all angles, and the Q rd iteration of the reconstructed image is completed, realizing the task of high-quality 3D scene image surface reconstruction. The iterative formula is denoted as:

$$f_j^{(Q+1)} = f_j^{(Q)} + \frac{\lambda_Q}{\sum_{i=1}^{M} a_{ij}} \sum_{i=1}^{M} \left[\frac{p_i - \sum_{n=1}^{N} a_{in} f_n^{(O)}}{\sum_{n=1}^{N} a_{in}} \right] a_{ij} \tag{20}$$

The process of 3D scene image surface reconstruction under virtual reality technology is shown in Figure 2.

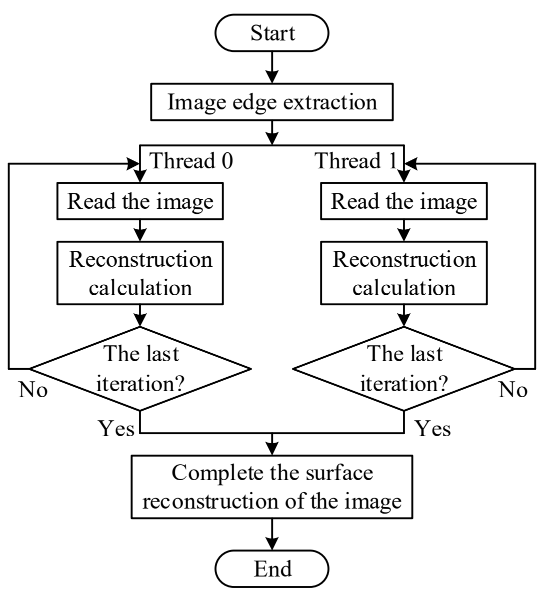

Figure 2: 3D scene image surface reconstruction process in virtual reality technology

IV. Testing of a virtual set-based movie animation special effects system

IV. A. System development environment

In order to realize the virtual scene automatic construction system based on procedural generation technology, it is necessary to clarify the hardware environment for system development, as well as the related libraries, related software development kits (SDK) and other software environments on which the system development depends.

(1) Hardware environment

Program generation technology requires high hardware specifications, in order to be able to stably carry out program generation and related content persistent storage, while timely rendering and displaying the generated virtual scene.

The hardware environment for the development of this system is shown in Table 1.

Table 1: The hardware environment of this system development

Configuration item	Explanation
CPU	Ryzen Zen3 5900x
Memory	64GB RAM
Local hard drive	1T SSD + 2T HDD
GPU	NVIDIA GeForce RTX 3090

(2) Software environment

In order to make this system can be well combined with the graphics engine, which is convenient for users to use. At the same time, in order to be able to meet the functions required for system design and analysis, this system is mainly developed by combining Houdini and Unreal Engine.

The detailed software environment required for the development of this system is shown in Table 2.

Table 2: The software detailed environment for the development of this system

Configuration item	Explanation
Operating system	Windows 11 Insider
Database	MongoDB 3.6.21
Unreal Engine	4.26.1(source code)
Houdini	Houdini Indie 18.5.696(Python3)
Houdini Engine	Unreal 4.26-v2
Python	3.7.1
Integrated development software	Visual Studio 2023Community)

IV. B. System real-time analysis

This section from multiple perspectives to achieve a number of groups of experimental effects, through the comparison with the real phenomenon shows that the simulation effect of the virtual generation system of multi-factor scenes is closer to the real effect. Through the experimental effect, it is verified that the virtual scene realized in this paper is more realistic, and the real-time effect is faster. In order to verify this, the real-time frame rate is monitored by recording the entire experimental process. Record the frame rate of the experiment at different times and different rendering qualities to verify the real-time nature of the experiment in this paper.

The frame rates for different rendering qualities are shown in Fig. 3. The representation in the figure shows the frame rate data comparison of this paper's experiments with different rendering qualities over time under Unity3D platform. The rendering quality of the virtual scene is categorized as Fastest, Simple, Good, and Fantastic. the fastest frame rate of this paper's system can reach 220.47 FPS in 20s.

From the change of frame rate, it can be seen that the experimental frame rate tends to stabilize with the increase of time, and the reason for the low frame rate of the premise is that the experiment is rendered by the method of forward rendering, so all the objects in the scene have to be computed and cropped and then rendered on the screen. Optical effect simulation is achieved through the piecewise shader part of the lighting model calculation, so as to obtain close to the real lighting effect, and this paper experiments to take full advantage of the powerful parallel computing capabilities of the GPU, a large number of lighting calculations through the GPU processing, which greatly improves the running speed of the experiment, which is also an important reason for the real-time nature of this experiment.

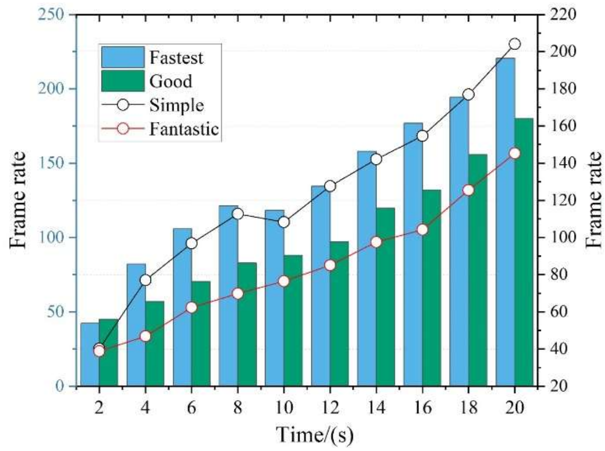

Figure 3: The frame rate of different rendering quality

IV. C. Automated Virtual Scenario Construction Testing

In the non-functional test, since the system is mainly used for real-time editing of virtual scenes by artists, scene modelers and other developers, the performance test of the system is mainly conducted during the construction of virtual scenes.

In the performance test when constructing virtual scenes, the system is mainly used to record the time and memory consumption of virtual scene construction to determine whether the procedural generation virtual scene construction system can meet the demand for real-time construction. In the test, different sizes of virtual scenes will be tested, in this test, the main four different sizes of the scene generation on the performance test, the generation of each type of virtual scene size for 10 times of random generation, and the results of the average. For fast scene editing and development, the overall generation time should be controlled within 5 minutes.

The performance test results for generation time are shown in Table 3. Where the unit of map size tested is m^2. In quantity, terrain generation is only used to generate height map and voxel files, so both are generated with fixed two files. In road generation, the generated quantity indicates the number of folded segments modeled for roads. In vegetation generation, the generated quantity is the number of vegetation point clouds in the whole scene. The generation quantity in the city building generation indicates the overall number of buildings in the city in the virtual scene.

The movie animation special effects system based on 3D virtual technology designed in this paper has a total generation time of 242.7s and a memory consumption of no more than 18.0GB in the 8192*8192 test, which is in line with the conditions of rapid scene editing.

Table 3: Performance test results for generated time

Test case		Landform generation	Road generation	Vegetation formation	Scenario overall generation	Total generated time	Memory consumption
1024x1024	Quantity	5	1524	26532	60	13.5s	1.52GB
	Time	2.5s	3.2s	2.7s	5.1s		
2048x2048	Quantity	5	3286	60425	132	18.6s	3.46GB
	Time	2.5s	2.7s	3.0s	10.4s		
4096x4096	Quantity	5	6785	124365	320	61.2s	8.33GB
	Time	5s	5.5s	5.7s	45s		
8192x8192	Quantity	5	17895	324073	328541	242.7s	17.69GB
	Time	12.5s	10.4s	10.2s	209.6s		

In order to test and analyze whether the system's demand analysis and immersion experience are up to standard, a questionnaire is designed around the system's various indicators. By providing VR system experience to 50 volunteers and counting the experience feedback. The results show that the system performs relatively well in the indicators of tree visualization, immersive scene experience, and the actual operation of the system, and completes the system demand target.

Comparison of the frame rate of rendering multiple trees and few trees of this system is shown in Figure 4, the frame rate of rendering multiple trees and the smoothness of rendering few trees of this system are higher than 60FPS.

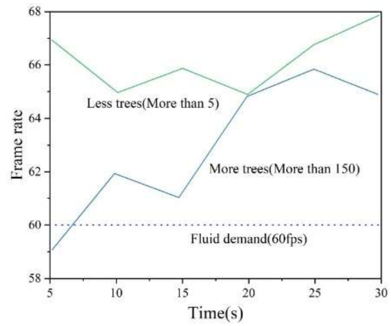

Figure 4: Render the comparison of the frame rate of several trees and the few trees

IV. D. Survey of Virtual Scene Animation Experience

The results of the survey on the experience of the movie animation special effects system based on 3D virtual technology are shown in Figure 5, which is rated in five dimensions, namely, “poor, qualified, good, more excellent, and very excellent”. From the figure, it can be seen that the animation special effects system in all aspects of the “more excellent” accounted for a prominent proportion. 34 out of 50 volunteers think that the stability of the movie animation special effects system is more excellent, recognizing the stability of the movie animation special effects system.

Comprehensive, rigorous and standardized tests were conducted in the user site environment in terms of function, performance, environment, reliability and user interface. Design system analysis and testing program, as well as fluency and immersion of the relevant test investigations, according to show the results of the system's functional use cases and non-functional objectives of the aspects of the completion to the expected demand for software, in line with the relevant design requirements, and has the following characteristics:

(1) The system architecture is reasonable and concise, and the system structure is clear and unambiguous, which can meet the target requirements.

(2) The functions are relatively comprehensive. The system consists of scene management and control module, scene model library, collision detection and terrain detection, view rendering module, motion camera module, etc. It covers business functions such as tree visualization, realism rendering and immersive roaming experience.

(3) The system has better security and adopts Adobe After Effects software to ensure real-time operation of view rendering. There is no dramatic change of screen articulation in the system, and the fluency is high.

(4) The system is flexible in use. The system realizes six-degree-of-freedom roaming and collision detection in line with the physical rules, and users can carry out panoramic roaming and observation experience.

(5) High system reliability. For users to restart the device after power failure or forced shutdown, they can continue to follow the default way and re-run this system for experience.

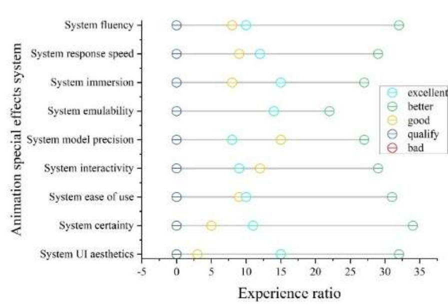

Figure 5: Experience of the animation effects system

V. Conclusion

This paper synthesizes the development of movie special effects technology and designs a movie animation special effects system based on three-dimensional virtual technology. Analyze the automatic construction effect of the movie animation special effects system based on 3D virtual technology on the virtual scene.

In the real-time analysis of the multi-group movie animation special effects system, it can be seen that the experimental frame rate tends to stabilize with the increase of time by the change of the frame rate of the rendering quality. In this paper, the system achieves the calculation of the lighting model by using the piecewise shader part to obtain the lighting effect close to the real one. And a large number of lighting calculations are given to the GPU processing, which improves the running speed of the experiment and makes the special effects system in this paper have the advantage of real-time. In the performance test of four different sizes of scene generation, the movie special effects system designed in this paper can complete the scene construction within 250s to meet the needs of virtual scene construction. In the virtual scene test of the movie animation special effects system, half of the volunteers recognized the stability, smoothness, ease of use, and UI beauty of the system.

References

[1] Dinç, İ. D. (2023). Animation & visual effects technologies influence on global production trends & digitalization of cinema from 1990 to 2020. Journal of Arts, 6(1), 83-98.

[2] Johnston, K. M., & Rickards, C. (2019). The spectacle of realism: special effects at Ealing Studios, 1940–45. Screen, 60(2), 261-279.

[3] Westerdale, J. (2023). Special Effects and German Silent Film: Techno-Romantic Cinema. German Quarterly, 96(1), 132-134.

[4] Elliott, A. B. (2020). Special effects and CGI in the biblical epic fi lm. In The Bible onscreen in the new millennium (pp. 50-67). Manchester University Press.

[5] Stewart, G. (2017). Digital Mayhem, Optical Decimation: The Technopoetics of Special Effects. Journal of Popular Film and Television, 45(1), 4-15.

[6] Tian, Y., & Chen, Y. (2022, January). Research on Visual Design of Computer 3D Simulation Special Effects Technology in the Shaping of Sci-Fi Animation Characters. In 2022 IEEE 2nd International Conference on Power, Electronics and Computer Applications (ICPECA) (pp. 1080-1083). IEEE.

[7] Saber, M. W. (2017). The Technological Development of Visual Effects and the Animation Character in Life Action. International Design Journal, 7(4), 51-56.

[8] Rogers, A. (2016). Classical Hollywood, 1928–1946: Special/Visual Effects. Editing and Special/Visual Effects, 68-77.

[9] Zhang, J. (2021). Application analysis of special effects technology in film and television post-production. In Frontier Computing: Proceedings of FC 2020 (pp. 1007-1013). Springer Singapore.

[10] Wang, D. (2022). Application Prospect of Film and TV Special Effects Synthesis Technology Under Digital. Frontier Computing: Proceedings of FC 2021, 827, 237.

[11] Zhang, W., & Wang, Y. (2020). Analyze the application of multimedia Technology in the Special Effects of film and television animation-from the animated short film of" day after day". International Journal of Social Science and Education Research, 2(11), 10-15.

[12] Sun, L. (2022). Research on the application of 3D animation special effects in animated films: Taking the film Avatar as an example. Scientific Programming, 2022(1), 1928660.

[13] Liu, X. (2022). Animation special effects production method and art color research based on visual communication design. Scientific Programming, 2022(1), 7835917.

[14] Zhang, J. (2024). Visual Communication Method of Multi frame Film and Television Special Effects Images Based on Deep Learning. Scalable Computing: Practice and Experience, 25(6), 5460-5468.

[15] Das, S. (2023). The evolution of visual effects in cinema: A journey from practical effects to CGI. JETIR: Journal of Emergıng Technologies and Innovative Research, 10(11), 303-09.

[16] Sabre, M. W. M. S. (2022). The Digital Technology of Visual Effects and its Impact on Egyptian Film. International Design Journal, 12(5), 51-56.

[17] Neo, P. X., & Loh, Y. L. (2022). Malaysian Film and Visual Effects Industry: Challenges and Future. Quarterly Review of Film and Video, 39(2), 308-322.

[18] Aghany, I. O. (2018). Computer graphics, animation and special effects: a creative way of producing Igbo-themed Nollywood movies for the global audience. Journal of African Films and Diaspora Studies, 1(2), 9.

[19] Wang, Y. (2022, January). Film and television special effects production based on modern technology: from the perspective of statistical machine learning. In 2022 4th International Conference on Smart Systems and Inventive Technology (ICSSIT) (pp. 833-836). IEEE.

[20] Stuckey, A. (2021). Special effects and spectacle: integration of CGI in contemporary Chinese film. Journal of Chinese Film Studies, 1(1), 49-64.

[21] Pamuji, S. A. (2023). ADOBE AFTER EFFECTS SOFTWARE VIDEO EDITING DAN MOTION GRAPHICS YANG POPULER. Sainsbertek Jurnal Ilmiah Sains & Teknologi, 4(1), 66-69.

[22] Pirmansah, I. A., & Munir, M. M. (2024). Analysis of the Effectiveness of Combination of Manual Keyframes and Expressions in Creating Animations Using Adobe After Effects. SMART: Jurnal Teknologi Informasi dan Komputer, 3(2), 89-97.

[23] Dockery, J., & Chavez, C. (2019). Learn Adobe After Effects CC for Visual Effects and Motion Graphics. Peachpit Press.

[24] MUHAMMAD RIZA, M. R. (2024). Pembuatan animasi 2 dimensi motion graphic pengaruh pengguna game online pada siswa SDN Jambu menggunakan adobe after effect. Online Repository of Universitas NU Kalimantan Selatan, 1-10.

[25] Supriyadi, S. (2019). Pemanfaatan Plugin After Effect Untuk Produksi Film. Jurnal Komunikasi, 10(1), 33-41.

[26] Boyang You & Barmak Honarvar Shakibaei Asli. (2024). A Model Development Approach Based on Point Cloud Reconstruction and Mapping Texture Enhancement. Big Data and Cognitive Computing,8(11),164-164.

[27] Hao Sun,Junping Qin,Zheng Liu,Xinglong Jia,Kai Yan,Lei Wang... & Shaofei Gong. (2025). Generation driven understanding of localized 3D scenes with 3D diffusion model. Scientific Reports,15(1),14385-14385.